ROBERTSON RESEARCH PETROLEUM SERVICES LIMITED

REPORT NO. 4194P

REPORT ON A GEOCHEMICAL EVALUATION OF THE 15/5 - 1 WELL, NORWEGIAN NORTH SEA.

by

B. S. COOPER

M. J. GIBBONS

P. C. BARNARD

A. G. COLLINS

J. McEWAN

PROJECT NO. RRPS/789/D/2641

Prepared by:

Robertson Research Petroleum Services Limited,
Ty'n-y-Coed,
Llanrhos,
Llandudno,
Gwynedd LL30 1SA,
Wales,
U.K.

Prepared for:

Norsk Hydro a.s.,
Postboks 2594, Solli,
Oslo 2,
Norway.

June, 1978

CONTENTS

TABLES

CONTENTS (Cont'd)

FIGURES

ENCLOSURE

SUMMARY

In the interval 1500 to 3750 metres of the Norsk Hydro 15/5-1 well, Norwegian North Sea, oil-prone organic matter approaches maturity at approximately 2300 metres. In contrast, gas-prone organic material is mature at approximately 3500 metres.

The Cretaceous and Tertiary sediments above 3490 metres are either too immature or too organically lean to source significant amounts of hydrocarbons. The Middle and Upper Jurassic shales and coals between 3490 and 3750 metres are presently capable of sourcing oil and/or gas, and at optimum maturity, off-structure, will have generated considerable quantities of hydrocarbons.

I

INTRODUCTION

This report, based on the results of analyses of 48 canned samples of ditch cuttings and 7 sidewall cores, assesses the maturation level and hydrocarbon source potential of the interval 1500 to 3752.5 metres of the Norsk Hydro 15/5-1 well, Norwegian North Sea.

Following analysis of the airspace gases, the cuttings were washed, dried and described. With few exceptions, the cuttings were of good quality. All samples were analysed for organic carbon content and 14 were selected for gasoline analysis. On the basis of the organic carbon data, 16 samples were submitted for pyrolysis and 18 samples subjected to full extractive source rock analysis. Additionally, the saturate fractions from 10 of the 18 extracts, and pentane extracts of 6 (10-metre) composite samples from the interval 3350 to 3560 metres, were analysed by gas chromatography. For the determination of spore colours, palynological preparations were made from 21 samples. Portions of 20 of these preparations, and 6 additional samples, were used for vitrinite reflectivity measurements.

The age of this section ranges from Middle Jurassic to Tertiary.

RESULTS AND INTERPRETATION

A. MATURITY EVALUATION

A.1 Light Hydrocarbon Analysis

a. Airspace Gas Analysis

Aliquots of airspace gas from the sealed sample cans were analysed to determine the amounts and percentage compositions of the C_1 to C_4 hydrocarbons. The results are presented in Table 1 and Figure 1.

Methane, of probable biogenic origin, is the sole component of the airspace gases to a depth of 2150 metres. On the basis of wet gas (C_2 to C_4) content, the section below 2150 metres is mature. The abrupt appearance of the wet gases at this depth may indicate the presence of an unconformity.

b. Gasoline Analysis

The presence of at least 8 to 10 of the individual C_4 to C_7 hydrocarbons in approximately equal quantities is considered to be an indication of maturity. The data presented in Table 2 and Figure 2 suggest that the section is transitionally mature between 1500 and 2050 metres and mature below the latter depth. However, variations in lithology and sampling technique somewhat obscure the overall picture.

A.2. Spore Colour

The level of maturity of the oil-prone organic matter present in kerogen concentrates was assessed by visual examinatiom of the indigenous sporomorphs. With increasing thermal maturity, spore colours change from pale yellow, through orange and brown to black. Spore colouration indices used in this report are based on the Robertson Research scale of 1 to 10,

with values of 3.0 to 3.5 representative of the narrow transition zone between maturity and immaturity.

A total of 21 samples was selected for spore colour determinations. The results are given in Table 3 and Figure 3. Generally the quality of the assemblages was poor, but the results are in acceptable agreement with other maturity data in suggesting that the section is transitionally mature between 1500 and 2375 metres and mature below this interval.

A.3 Vitrinite Reflectivity

Vitrinite, a type of humic, gas-prone organic matter is considered to be transitionally mature over the reflectivity range 0.4 to 0.5 per cent, but would not be expected to yield prolific gas until values in excess of 0.8 to 1.0 percent had been attained. Although vitrinite is not an important oil source it is the only reliable maturation indicator in the organically metamorphosed zone.

During this study 26 samples were examined for vitrinite. The reflectivity data are given in Table 3 and Figure 4.

The data indicate that gas-prone organic matter is mature at approximately 3500 metres. Generally the numbers and quality of the vitrinite particles present were low, and the kerogen concentrates tended to be dominated by inertinite, a humic maceral with only minor gas-generating potential. Reworked and/or caved populations of vitrinite were observed in several samples. Although of variable composition and reflectance, the vitrinitic components of the Middle Jurassic coals yielded consistently higher values (ca. 0.65 to 0.70 per cent) than vitrinitic material from associated shales (0.55 to 0.57 percent).

A.4 Comparison of Maturation Indices

The airspace gas and gasoline data are comparable and suggest that maturity is attained between 2050 and 2150 metres. Similarly, spore colours suggest that oil-prone organic matter is mature below 2375 metres. In contrast, vitrinite reflectivity results indicate that gas-prone organic matter is immature to a depth of approximately 3500 metres. Both spore colour and vitrinite reflectivity data show a rapid increase in thermal maturity within the Middle and Upper Jurassic sequence. This phenomenon could be due to either abnormally high geothermal gradients during the lower Cretaceous-Upper Jurassic or the rapid increase in geothermal gradients characteristic of overpressured sections.

B. SOURCE ROCK EVALUATION

B.1 Organic Carbon Content

All samples were analysed for organic carbon content. The results for the bulk samples and some hand-picked lithologies are given in Table 4. Using these values the section may be divided into four: between 1500 and 1700 metres, above average contents (i.e. more than 2 per cent organic carbon); 1700 to 2400 metres, fair (i.e. between 0.3 and 1.0 per cent); 2400 to 3450 metres, lean to fair; 3450 to 3750 metres, above average.

B.2 Solvent Extraction

On the basis of the organic carbon data, 18 samples were selected for full source rock analysis. The results are given in Table 4 and summarised in Figure 7. A brief inspection of Figure 7 shows that the section falls into two unequal and contrasting parts; the Cretaceous and Tertiary above 3500 metres and the Middle and Upper Jurassic between 3500 and 3750 metres. Above 3500 metres the section is either insufficiently mature or too organically lean to have sourced significant quantities of hydrocarbons, although the true picture is slightly obscured by the presence of migrant hydrocarbons. Even at optimum maturity off-structure these rocks are unlikely to source appreciable amounts of hydrocarbons.

The Middle and Upper Jurassic coals and shales between 3500 and 3750 metres constitute a good oil and/or gas source. The data indicate that their lateral equivalents at greater depths off-structure will have sourced significantly greater quantities of hydrocarbons. The gas chromatograms of Figure 8 and the data of Tables 1 and 2 suggest that, at their present level of maturity they are producing a heavy oil with condensate and wet gas.

B.3 Gas Chromatography

Following source rock analysis, the saturated-hydrocarbon fractions of 10 samples were analysed by gas chromatography. Samples from 1650, 2300 and 3300 metres produced distributions which strongly suggested the presence of migrant hydrocarbons rather than indigenous hydrocarbons. Figure 8 shows 3 chromatograms characteristic of the most promising source rock interval i.e. the Middle and Upper Jurassic coals and shales between 3500 and 3750 metres.

The n-alkanes of the Upper Jurassic samples extend beyond C_{33} and possess either a unimodal distribution with a maximum at C_{15}, C_{16} or C_{17}, or a slightly bimodal distribution with an additional maximum at C_{23} or C_{25}. Carbon preference indices (CPI values) approach unity. Consideration of the initial maturity of this sequence and the lack of a marked odd-carbon number preference in the C_{27} to C_{33} n-alkanes suggest a predominantly lower plant (sapropelic) origin for the hydrocarbons. However, the high pristane/phytane ratio (4.7) of the sample from 3700 metres is typical of coaly sediments containing abundant terrestrial higher plant debris. Consequently the low CPI value may indicate that the hydrocarbons were generated at greater depths off-structure and migrated up-dip. On the other hand the presence of steranes and triterpanes confirms that the shales have not been heated excessively.

Pristane/phytane pristane/n-C_{17} and phytane/n-C_{18} ratios vary from 0.95 to 4.7, 0.78 to 1.8 and 0.4 to 0.93 respectively. The range of values is due to variations in the proportion of coaly material in each sample.

B.4 Pyrolysis

The pyrolysis technique involves the heating of samples from 250° to 550°C over a period of approximately 15 minutes. During this time, three pulses of gases are released and recorded as weights of gas. The first of these pulses relates to hydrocarbons present in the sediment which could

normally be extracted by organic solvents; these are either the adsorbed hydrocarbons indicating present source potential, or reservoired hydrocarbons. The second gas pulse is of hydrocarbons released by the thermal breakdown of kerogen (optimum source potential), and simultaneously the temperature of maximum rate of evolution is measured. The third pulse is of carbon dioxide.

The parameters used in interpretation are the hydrogen index (ratio of released hydrocarbons to organic carbon content), the oxygen index (ratio of released carbon dioxide to organic carbon content), the temperature of maximum rate of pyrolysis, and the production index (ratio of the ammount of hydrocarbons released in the first stage of heating to the total amount of released hydrocarbons). Kerogens rich in sapropelic matter exhibit a high hydrogen index and a low oxygen index while those in which humic debris predominates will display a low hydrogen index and a high oxygen index. Hydrogen and oxygen indices for a particular type of kerogen are also susceptible to a reduction in their values during the course of thermal maturation. The fields for typical kerogen assemblages are shown in Figure 6.

The hydrogen index is a measure of the hydrocarbon generating potential of the kerogen. Immature, organically rich source rocks and oil shales give values above 550, mature oil source rocks give values between 200 and 550.

The temperature of maximum rate of pyrolysis depends on the nature of the organic matter, but the transition from immature to mature organic matter is marked by temperatures between 415° and 435°C. The maturity transition from oil and wet gas generation to dry gas generation is marked by temperatures between 455° and 460°C. In practice, greater variation than these ideal temperature ranges may be seen, but they are nevertheless useful as general guides to the level of maturity attained by the sediment.

The production index increases with maturity from values near zero for

immature organic matter to maximum values of 0.30 during the late stages of oil generation. Anomalously high values indicate the presence of free oil. The hydrocarbon yield is an indication of the potential yield of hydrocarbons from the source rock at optimum maturity and is a measure of the quality of the source rock. A value of 0 to 2000 ppm of hydrocarbon in the rock characterises a poor source rock, 2000 to 6000 ppm fair, 6000 to 20,000 ppm good and above 20,000 ppm very good.

The pyrolysis data presented in Table 5 and Figures 5 and 6 confirm that the best hydrocarbon source rocks occur between 3450 and 3750 metres. The high potential yields for this interval indicate that its lateral equivalents at greater depths off-structure will have acted as significant hydrocarbon sources. The anomalously high production indices of several of the shallower samples suggest the presence of migrant hydrocarbons.

B.5 Visual Examination of Kerogen

Visual examination of the palynological preparations showed that between 1500 and 3500 metres samples yield kerogens dominated by inertinite and, to a lesser degree, vitrinite, both humic materials with variable gas-generating potential. Oil-prone sapropelic organic matter is more abundant in the interval 3500 to 3650 metres. Samples between 3650 metres and T.D. contain approximately equal amounts of inertinite and vitrinite with subordinate sapropel.

C. INVESTIGATION OF LOWER CRETACEOUS RESIDUAL OIL

Significant quantities of an apparently dead residual oil were observed in cuttings samples (from the Lower Cretaceous. This material was investigated through cold pentane extraction followed by gas chromatography of the total extracts. Figure 9 shows 3 chromatograms which are characteristic of the interval as a whole. The distributions are bimodal with maxima in the gasoline range and at $\underline{n}$-C_{16}. This distinctive distribution appears at 3350 metres and extends to 3500 metres i.e. ranges from the top of the Upper Jurassic into the Lower Cretaceous.

The isoprenoid hydrocarbons are generally present in minor amounts only, resulting in unusually low pristane/$\underline{n}$-C_{17} and phytane/$\underline{n}$-C_{18} ratios, eg. both less than 0.1 in one instance. The pristane/phytane ratios themselves are not abnormal.

Assuming that the distributions are natural, there are at least two possible explanations for these observations. Either the distributions represent a mixture of a heavy dead residual oil and a heavy gas condensate, or else the heavy oil and condensate are the product of a source rock in the earliest stage of maturity.

CONCLUSIONS

1. Oil-prone organic matter in the Norsk Hydro 15/5-1 well is mature below approximately 2300 metres.

2. Gas-prone organic matter is mature below approximately 3500 metres.

3. The Cretaceous and Tertiary sediments above 3490 metres are too immature and too organically lean to source significant quantities of hydrocarbons.

4. The Middle and Upper Jurassic shales and coals between 3490 and 3750 metres are good present oil and/or gas sources and will have even greater potential at depth off-structure.

TABLE 1

AIRSPACE GASEOUS HYDROCARBON ANALYSIS DATA

COMPANY: NORSK HYDRO **WELL:** 15/5-1 **LOCATION:** NORWEGIAN NORTH SEA

DEPTH (Metres)	RELATIVE GASEOUS HYDROCARBON COMPONENT ABUNDANCES (PER CENT)					TOTAL ABUND - ANCE (ppm)	TOTAL $C_2 - C_4$ (Per Cent)	RATIO i - Butane / n - Butane
	C_1	C_2	C_3	i - C_4	n - C_4			
1500	-	-	-	-	-	-	-	-
1550	100	*	*	*	*	18200	*	*
1600	100	*	*	*	*	17800	*	*
1650	100	*	*	*	*	15620	*	*
1700	100	*	*	*	*	13080	*	*
1750	-	-	-	-	-	-	-	-
1800	100	*	*	*	*	7920	*	*
1850	-	-	-	-	-	-	-	-
1900	100	*	*	*	*	1224	*	*
1950	-	-	-	-	-	-	-	-
2000	100	*	*	*	*	1512	*	*
2050	100	*	*	*	*	780	*	*
2100	100	*	*	*	*	1080	*	*
2150	76	11	13	*	*	4540	24	*
2200	75	10	15	tr	tr	6009	25	*
2250	100	*	*	*	*	5160	*	*
2300	68	13	19	*	*	8627	32	*
2350	64	15	*	21	*	497	36	*
2375	*	tr	*	tr	*	*	*	*
2400	56	19	18	3.5	3.5	4892	44	1.0
2450	91	5	4	*	*	1568	9	*
2500	77	10	10	1.5	1.5	2826	23	1.0
2550	15	19	45	21	*	808	85	*
2600	-	-	-	-	-	-	-	-
2650	81	9	8	1.5	1.5	657	19	1.0
2700	99	0.5	0.5	*	tr	264	1	*
2750	99	0.5	0.5	*	tr	98	1	*

NOTE: TOTAL GASEOUS HYDROCARBON ABUNDANCE VALUES ARE EXPRESSED AS VOLUME OF HYDROCARBON GASES RELATIVE TO VOLUME OF AIRSPACE.

TABLE 1 (Cont'd.)

AIRSPACE GASEOUS HYDROCARBON ANALYSIS DATA

COMPANY: NORSK HYDRO **WELL:** 15/5-1 **LOCATION:** NORWEGIAN NORTH SEA

DEPTH (Metres)	RELATIVE GASEOUS HYDROCARBON COMPONENT ABUNDANCES (PER CENT)					TOTAL ABUND - ANCE (ppm)	TOTAL $C_2 - C_4$ (Per Cent)	RATIO i - Butane / n - Butane
	C_1	C_2	C_3	i - C_4	n - C_4			
2800	99	1	tr	*	tr	361	1	*
2850	6	5	52	7	30	1962	94	0.23
2900	36	2	33	7	22	193	64	0.32
2950	29	tr	19	tr	52	41	71	*
3000	100	*	*	*	*	137	*	*
3050	90	3	7	*	*	170	10	*
3100	53	4	43	*	*	181	47	*
3150	74	7	19	*	*	129	16	*
3200	25	tr	30	8	37	165	75	0.22
3250	51	5	27	*	17	75	49	*
3300	66	32	2	*	tr	1821	34	*
3350	100	tr	*	*	*	144	*	*
3400	93	7	*	*	*	732	7	*
3450	94	6	*	*	*	898	6	*
3500	25	18	43	3	21	42770	75	0.14
3525	49	20	22	1.5	7.5	30460	51	0.20
3550	22	16	38	5	19	46340	88	0.26
3600	42	24	24	2	8	86100	58	0.25
3650	69	21	9	*	1	26320	31	*
3700	78	16	4	0.5	0.5	205500	21	1.0
3750	61	19	13	2	5	179000	39	0.4

NOTE: TOTAL GASEOUS HYDROCARBON ABUNDANCE VALUES ARE EXPRESSED AS VOLUME OF HYDROCARBON GASES RELATIVE TO VOLUME OF AIRSPACE.

TABLE 2

GASOLINE HYDROCARBON ANALYSIS DATA

COMPANY: NORSK HYDRO WELL: 15/5-1 LOCATION: NORWEGIAN NORTH SEA

DEPTH: METRES	1500	2050	2400	2600	2900	3350	3450
GASOLINE HYDROCARBON COMPONENTS	RELATIVE GASOLINE HYDROCARBON COMPONENT ABUNDANCES (PER CENT)						
i - BUTANE	*	Tr	*	Tr	*	*	*
n - BUTANE	*	Tr	*	Tr	*	*	*
i - PENTANE	*	5	*	*	*	*	*
n - PENTANE	*	9	Tr	Tr	*	*	*
2,2 - DIMETHYL BUTANE	*	*	*	Tr	*	*	*
CYCLOPENTANE	*	*	*	Tr	*	*	*
2,3 - DIMETHYL BUTANE	*	*	*	*	*	*	*
2 - METHYL PENTANE	*	3	*	Tr	*	*	*
3 - METHYL PENTANE	*	*	*	Tr	*	*	*
n - HEXANE	7	7	*	Tr	*	*	*
METHYL CYCLOPENTANE	11	*	*	*	*	*	*
2,2 - DIMETHYL PENTANE	*	*	*	*	*	*	*
2,4 - DIMETHYL PENTANE	*	*	*	*	*	*	*
BENZENE	*	3	*	Tr	*	10	87
CYCLOHEXANE	*	7	*	Tr	*	*	*
3,3 - DIMETHYL PENTANE	*	*	*	*	*	*	*
2 - METHYL HEXANE	15	4	*	*	*	*	*
1,1 - DIMETHYL CYCLOPENTANE	*	*	*	*	*	*	*
3 - METHYL HEXANE	33	13	*	Tr	*	*	*
1, CIS - 3 - DIMETHYL CYCLOPENTANE	*	*	*	*	*	*	*
1, TRANS - 3 - DIMETHYL CYCLOPENTANE	*	*	*	*	*	*	*
1, TRANS - 2 - DIMETHYL CYCLOPENTANE	*	3	*	*	*	*	*
3 - ETHYL PENTANE	14	4	*	*	*	20	7
n - HEPTANE	*	8	Tr	Tr	*	35	*
1, CIS - 2 - DIMETHYL CYCLOPENTANE	*	3	*	*	*	*	*
METHYL CYCLOHEXANE	20	7	*	*	*	15	6
ETHYL CYCLOPENTANE	*	*	Tr	Tr	*	*	*
TOLUENE	*	6	Tr	Tr	*	20	*
TOTAL ABUNDANCE (PPB)	50	1200	10	20	< 5	20	42
ORGANIC CARBON (PER CENT)	2.52	0.72	0.61	0.49	0.24	0.33	0.58
GASOLINE ABUNDANCE AT 1 PER CENT ORGANIC CARBON	20	1667	16	41	*	61	72

NOTE: TOTAL GASOLINE ABUNDANCE VALUES ARE EXPRESSED AS WEIGHT OF GAS RELATIVE TO WEIGHT OF WET ROCK.

TABLE 2 (Cont'd.)

GASOLINE HYDROCARBON ANALYSIS DATA

COMPANY: NORSK HYDRO WELL: 15/5-1 LOCATION: NORWEGIAN NORTH SEA

DEPTH:	3500	3525	3550	3600	3650	3700	3750
GASOLINE HYDROCARBON COMPONENTS	RELATIVE GASOLINE HYDROCARBON COMPONENT ABUNDANCES (PER CENT)						
i - BUTANE	4	7	9	Tr	Tr	Tr	Tr
n - BUTANE	6	13	14	Tr	Tr	Tr	Tr
i - PENTANE	7	7	11	19	20	19	15
n - PENTANE	17	16	21	16	28	20	23
2,2 - DIMETHYL BUTANE	*	*	*	*	*	*	*
CYCLOPENTANE	2	2	2	2	2	2	2
2,3 - DIMETHYL BUTANE	*	*	*	*	*	*	*
2 - METHYL PENTANE	4	4	5	6	7	7	6
3 - METHYL PENTANE	3	3	3	4	2	2	3
n - HEXANE	9	7	8	9	6	6	8
METHYL CYCLOPENTANE	6	6	5	8	3	4	7
2,2 - DIMETHYL PENTANE	*	2	1	3	3	3	2
2,4 - DIMETHYL PENTANE	*	1	1	5	4	5	4
BENZENE	3	2	1	3	12	11	5
CYCLOHEXANE	4	3	3	4	3	2	4
3,3 - DIMETHYL PENTANE		2	1	2	1	1	2
2 - METHYL HEXANE	4	3	3	*	*	*	*
1,1 - DIMETHYL CYCLOPENTANE	*	*	*	*	*	*	*
3 - METHYL HEXANE	4	4	3	3	1	2	3
1, CIS - 3 - DIMETHYL CYCLOPENTANE	*	*	*	*	*	*	*
1, TRANS - 3 - DIMETHYL CYCLOPENTANE	*	*	*	*	*	*	*
1, TRANS - 2 - DIMETHYL CYCLOPENTANE	*	*	*	*	*	*	*
3 - ETHYL PENTANE	3	1	1	2	<1	<1	<2
n - HEPTANE	7	6	Tr	4	2	3	4
1, CIS - 2 - DIMETHYL CYCLOPENTANE	*	*	*	*	*	*	*
METHYL CYCLOHEXANE	8	6	3	2	3	4	2
ETHYL CYCLOPENTANE	2	2	4	1	<1	<1	<1
TOLUENE	7	3	1	4	5	7	2
TOTAL ABUNDANCE (PPB)	235	1582	3062	26758	35891	1912	20636
ORGANIC CARBON (PER CENT)	4.05	8.72	9.05	8.51	16.77	10.97	8.04
GASOLINE ABUNDANCE AT 1 PER CENT ORGANIC CARBON	58	187	338	3148	2140	174	2567

NOTE: TOTAL GASOLINE ABUNDANCE VALUES ARE EXPRESSED AS WEIGHT OF GAS RELATIVE TO WEIGHT OF WET ROCK.

TABLE 3

MATURITY EVALUATION DATA

COMPANY: NORSK HYDRO WELL:15/5-1 LOCATION: NORWEGIAN NORTH SEA.

SAMPLE DEPTH METRES OR NOTATION	SAMPLE TYPE	GENERALISED LITHOLOGY	SPORE COLOUR INDEX (1-10)	VITRINITE REFLECTIVITY IN OIL, R ov %	FLUORESCENT MATERIAL IN REFLECTED BLUE LIGHT
1500	Ctgs	Med-dk gy/lt ol-gy sl calc sh	3-3.5	0.36 (21)	Dull yellow frags
1650	"	Ol-gy slty sh	3	0.35 (1)	Orng-brn/yel-brn spores
1800	"	Ol-gy/dk gn-gy sh	3.5	0.32 (2) 0.39 (10) 0.56 (1)	*
1950	"	Ol-gy/gn-gy sh	3.5	0.39 (3) 0.51 (20)	Dull golden-brn spores
2100	"	Ditto + med gy sh	3.5	0.36 (21)	Yel-orng spores
2250	"	Med gy/gn-gy sh	3-3.5	0.36 (10) 0.50 (3) 0.65 (2)	Ditto
2375	"	Ditto	4	0.36 (13)	Ditto
2500	"	Med gy sh + crs snd	?3	?0.45 (24)	Yel-orng spores + algal frags
2600	"	Med-dk gy/dk gn-gy sh	4	0.40(4) 0.66 (6)	Yellow algal frags
2650	"	Ditto	?3	?0.36 (1)	Dull orng-yel frags
2900	"	Wht/pnk-gy chk + mnr sh	4	?0.56(2)	*
3150	"	Lt gy/med gy marl + mnr sh	?4	?0.34 (4) ?0.56 (6)	Yel/yel-brn algal frags
3350	"	Wht lt gy chk + mnr sh	4	*	*
3450	"	Varicoloured sh	-	*	Yellow frags
3489	SWC	-	4	0.40(13)	Golden-yel spores
3493	"	-	*	*	Yellow frags
3525	Ctgs	Dk gy/ol-blk sh	4.5	0.46 (8)	Yel/yel-orng algal frags
3550	"	Dk gy sh	4.5	0.48 (3)	Yel/yel-orng spores
3600	"	Ol-blk slty sh	-	*	Ditto
3610	SWC	-	4.5	0.32 (5) 0.43 (9) 0.55 (5)	Ditto
3650	Ctgs	Dk gy slty sh/ coal	-	0.69 (13)	Ditto

TABLE 3 (cont'd)

MATURITY EVALUATION DATA

COMPANY: NORSK HYDRO WELL : 15/5-1 LOCATION: NORWEGIAN NORTH SEA.

SAMPLE DEPTH OR NOTATION	SAMPLE TYPE	GENERALISED LITHOLOGY	SPORE COLOUR INDEX (1-10)	VITRINITE REFLECTIVITY IN OIL, R ov %	FLUORESCENT MATERIAL IN REFLECTED BLUE LIGHT
3655	SWC	-	5	-	-
3700	Ctgs	Brn-gy slty sh/coal + sst	-	0.66 (10)	Yel/yel-orng spores
3705	SWC	-	4.5	0.57 (5)	Yellow spores
3745	"	-	*	*	*
3750	Ctgs	Brn-gy slty sh/coal + sst	-	0.65 (18)	Dull yel/yel-orng spores
3752.5	SWC	-	-	0.57 (9)	Yellow spores

TABLE 4

SOURCE ROCK EVALUATION DATA

COMPANY: NORSK HYDRO WELL: 15/5-1 LOCATION: NORWEGIAN NORTH SEA

SAMPLE DEPTH (METRES OR NOTATION	SAMPLE TYPE	ANALYSED LITHOLOGY	ORGANIC CARBON % OF ROCK	TOTAL EXTRACT P.P.M.	EXTRACT % OF ORGANIC CARBON	HYDRO--CARBONS P.P.M. OF ROCK	HYDRO-CARBONS % OF EXTRACT	TOTAL ALKANES % HYDRO-CARBONS
1500	Ctgs	Med-dk gy glauc, slty sl calc sh+40% lt ol-gy slty sl calc sh	2.52	976	3.8	170	17	70
1550	"	Ol-gy sl calc slty sh +40% med-dk gy slty glauc sh	2.47					
1600	"	Ol-gy/med-dk gy sl calc slty sh	2.02					
1650	"	Ol-gy slty sh+drilling mud	2.33	2300	9.8	280	12	71
1700	"	Gn-gy sh+40% ol-gy sh+mnr drilling mud+ slt	1.20					
1750	"	Ol-gy/dk gn-gy sh+mnr drilling mud+slt	0.94					
1800	"	Ditto+ditto+ditto	0.84	1267	15.1	140	11	86
1850	"	Lt ol-gy/ol-gy sh+10% glauc sst	0.83					
1900	"	Ol-gy/dk gn-gy sh+ mnr yel-gy/brn-gy/dk gy sh	0.71					
1950	"	Ol-gy sh+10% gn-gy sh +mnr lt ol-gy sst/dk gy snd	0.46	619	13.2	215	35	57
2000	"	Dk gn-gy sh+mnr ol-gy/ dk gy sh+mnr lt ol-gy sst	0.76					
2050	"	Dk gn-gy sh+10% ol-gy sh+10% gy-red sh+mnr lt ol-gy/brn-gy/gn-gy sh	0.72					
2100	"	Ol-gy sh+30% med gy sh+10% gy-red/gn-gy/ lt ol-gy sh	0.75	613	8.2	255	42	70
2150	"	Med-dk gy sh+20% gy-red/gn-gy/lt ol-gy/ brn-gy sh+mnr pyrite	0.81					
2200	"	Ditto+ditto+ditto	0.63					
2250	"	Med gy sh+30% gn-gy sh+10% lt ol-gy/gy-red/brn-gy sh+mnr drilling mud+mnr pyrite+mnr wht chk	0.56					

TABLE 4 (Cont'd.)

SOURCE ROCK EVALUATION DATA

COMPANY: NORSK HYDRO WELL: 15/5-1 LOCATION: NORWEGIAN NORTH SEA

SAMPLE DEPTH METRES OR NOTATION	SAMPLE TYPE	ANALYSED LITHOLOGY	ORGANIC CARBON % OF ROCK	TOTAL EXTRACT P.P.M.	EXTRACT % OF ORGANIC CARBON	HYDRO-CARBONS P.P.M. OF ROCK	HYDRO-CARBONS % OF EXTRACT	TOTAL ALKANES % HYDRO-CARBONS
2300	Ctgs	Vari-coloured shales	0.60	873	14.5	315	36	69
2350	"	Med gy sh+30% v lt gy sltst+mnr lt ol-gy/gy-red sh	0.53					
2375	"	Med gy fe stained sh+ 20% gn-gy sh+mnr lt ol-gy/gy-red/lt brn sh	0.43					
2400	"	Med gy sh+mnr lt ol-gy/gy-red/gn-gy sh+ 20% clean crs snd	0.61					
2450	"	Clean crs snd+10% med gy/gn-gy/red-brn sh	0.20					
2500	"	Med gy sh+15% clean crs snd+mnr gn-gy sh	0.61	1064	17.4	180	17	81
2550	"	Med-crs snd/sst+20% med gy/gn-gy/brn-gy sh	0.29					
2600	"	Med-dk gy/dk gn-gy sh +mnr crs snd+mnr brn-gy sltst+mnr lt ol-gy sh	0.49					
2650	"	Ditto+ditto+ditto+ ditto	0.21					
2700	"	Med gy sh+10% dk gy sh+mnr gy-red/gn-gy sh	0.31	495	15.9	270	55	53
2750	"	V lt/lt gy chk+15% med gy sh+occ pyr	0.24					
2800	"	Ditto+ditto	0.24					
2850	"	Wht-v lt gy/pnk-gy/ pale red chk+20% marl+10% med-dk gy sh	0.22					
2900	"	Ditto+ditto+ditto	0.24					
2950	"	Ditto+ditto+ditto	0.17					
3000	"	Ditto+ditto+ditto	0.22					
3050	"	Lt gy/med gy marl+ 10% pale red marl+ 5% med-dk gy sh	0.31					
3100	"	Ditto+ditto+ditto	0.39	1068	27.4	415	39	33

TABLE 4 (Cont'd.)

SOURCE ROCK EVALUATION DATA

COMPANY: NORSK HYDRO WELL: 15/5-1 LOCATION: NORWEGIAN NORTH SEA

SAMPLE DEPTH (METRES OR NOTATION	SAMPLE TYPE	ANALYSED LITHOLOGY	ORGANIC CARBON % OF ROCK	TOTAL EXTRACT P.P.M.	EXTRACT % OF ORGANIC CARBON	HYDRO-CARBONS P.P.M. OF ROCK	HYDRO-CARBONS % OF EXTRACT	TOTAL ALKANES % HYDRO-CARBONS
3150	Ctgs	Lt gy/med gy marl+ 10% pale red marl+5% med-dk gy sh	0.18					
3200	"	V lt gy chk+30% med-gy/gy-red calc sh	0.33					
3250	"	Ditto+20% ditto	0.17					
3300	"	Wht- v lt gy chk+15% med gy calc sh+mnr gy-red marl	0.32	334	10	245	74	39
3350	"	Ditto+ditto+ditto	0.33					
3400	"	Ditto+ditto+ditto+ drilling mud	0.49					
3450	"	Lt gy/med gy/dk gy/ gy red/gn-gy varie-gated sh	0.58	2760	47.5	220	8	23
3500	"	Dk gy sh+10% gy-red/ med gy sh	4.05	6415	15.8	2510	39	29
3525	"	Dk gy/ol-blk sh	8.72	19105	21.9	6730	35	44
3550	"	Ditto	9.05	24230	26.8	5670	23	44
3600	"	Ol-blk slty sh, occ glauc and pyr+10% yel-gy/gy-red sst	8.51	17705	20.8	7440	42	14
3650	"	Brn-gy/dk gy slty sh/ coal+mnr yel-gy sst	16.77	70304	41.9	11250	16	5
3700	"	Brn-gy slty sh/coal+ 25% v lt gy/lt-ol-gy sst	10.97	14857	12	2526	17	11
3750	"	Brn-gy/dk gy slty sh/coal+30% v lt gy/ gy-red/wht sst	8.04	13739	12.4	3435	25	14

TABLE 4 (Cont'd.)

SOURCE ROCK EVALUATION DATA

COMPANY : NORSK HYDRO WELL : 15/5-1 LOCATION : NORWEGIAN NORTH SEA

SAMPLE DEPTH METRES OR NOTATION	SAMPLE TYPE	ANALYSED LITHOLOGY	ORGANIC CARBON % OF ROCK	TOTAL EXTRACT P.P.M.	EXTRACT % OF ORGANIC CARBON	HYDRO-CARBONS P.P.M. OF ROCK	HYDRO-CARBONS % OF EXTRACT	TOTAL ALKANES % HYDRO-CARBONS
		HAND PICKED LITHOLOGIES						
1500	Ctgs	Lt ol-gy sh	1.81					
1500	"	Med-dk sh	3.73					
1550	"	Ol-gy sh	2.70					
1550	"	Med-dk sh	4.23					
1800	"	Lt ol-gy sh	1.52					
1800	"	Gn-gy sh	1.03					
2050	"	Gn-gy sh	1.54					
2050	"	Lt brn-gy/lt ol-gy sh	0.72					
2050	"	Dk brn-gy/ol-gy sh	2.01					
2050	"	Gy-red sh	0.18					
2100	"	Med gy sh	2.19					
2150	"	Med-dk gy sh	1.81					
2200	"	Ditto	1.95					
2250	"	Gn-gy sh	1.35					
2250	"	Red-gy sh	0.11					
2250	"	Wht chk	0.26					
2375	"	Lt ol-gy sh	1.22					
2375	"	Lt brn/ol-gy sh	2.97					
2375	"	Gn-gy sh	1.73					
2850	"	Pnk-gy chk	0.13					
2850	"	Med-dk gy sh	0.58					
3150	"	Gy red sh	0.09					
3150	"	Med-dk gy sh	0.21					
3150	"	Pale red marl	0.09					
3450	"	Med-gy sh	0.19					
3450	"	Gy-red sh	0.24					
3450	"	Dk gy sh	5.67					
3500	"	Dk gy sh	3.88					
3525	"	Ol-blk sh	8.88					
3550	"	Ol-blk sh	9.99					
3650	"	Brn-gy slty sh	3.08					
3750	"	Dk gy sh	7.91					
3750	"	Wht sst	0.12					

TABLE 5

ROCK - EVAL. PYROLYSIS DATA

COMPANY: NORSK HYDRO WELL: 15/5-1 LOCATION: NORWEGIAN NORTH SEA

SAMPLE DEPTH (METRES) OR NOTATION	GENERALISED LITHOLOGY	ORGANIC CARBON (%)	TEMPERATURE (°C)	HYDROGEN INDEX	OXYGEN INDEX	PRODUCTION INDEX	POTENTIAL YIELD (PPM)
1500	Med-dk gy glauc slty sl calc sh+ 40% lt ol-gy slty sl calc sh	2.52	428	50	40	0.04	1300
1650	Ol-gy slty sh+ drilling mud	2.33	429	42	51	*	1000
1800	Ol-gy/dk gn-gy sh+mnr drilling mud+slt	0.84	425	23	37	0.20	200
1950	Ol-gy sh+10% gn-gy sh+mnr lt ol-gy sst/dk gy snd	0.46	425	16	135	0.50	100
2100	Ditto+30% med gy sh+10% gy-red/ gn-gy/lt ol-gy sh	0.72	427	38	59	0.12	300
2300	Vari-coloured shales	0.60	413	40	56	0.13	300
2500	Med gy sh+15% clean crs snd+ mnr gn-gy sh	0.61	409	21	50	0.16	100
2700	Ditto+10% dk gy sh+mnr gy-red/ gn-gy sh	0.31	*	*	411	*	*
2850	Wht-v lt gy/pnk-gy/pale red chk+ 20% marl+10% med-dk gy sh	0.22	*	*	313	*	*
3100	Lt gy/med gy marl +10% pale red marl+5% med-dk gy sh	0.39	*	95	294	0.56	100
3300	Wht - v lt gy chk+15% med gy calc sh+mnr gy-red marl	0.32	*	*	314	*	*
3450	Lt gy/med gy/dk gy/gy-red/gn-gy variegated sh	0.58	437	129	66	*	800
3525	Dk gy/ol-blk sh	8.72	436	415	3	0.19	36200
3600	Ol-blk slty sh, occ glauc and pyr+10% yel-gy/ gy red sst	8.51	432	228	10	0.12	19400
3650	Brn-gy/dk gy slty sh/coal+mnr yel-gy sst	16.77	437	136	6	0.08	22700

TEMPERATURE (°C) = TEMPERATURE AT MAXIMUM RATE OF PYROLYSIS
PRODUCTION INDEX = AN ESTIMATE OF PRESENT HYDROCARBON GENERATING POTENTIAL COMPARED TO THAT AT OPTIMUM MATURITY
POTENTIAL YIELD = AN ESTIMATE OF HYDROCARBON PRODUCTION AT OPTIMUM MATURITY

TABLE 5 (Cont'd.)

ROCK - EVAL. PYROLYSIS DATA

COMPANY: NORSK HYDRO WELL: 15/5-1 LOCATION: NORWEGIAN NORTH SEA

SAMPLE DEPTH (METRES) OR NOTATION	GENERALISED LITHOLOGY	ORGANIC CARBON (%)	TEMPERATURE (°C)	HYDROGEN INDEX	OXYGEN INDEX	PRODUCTION INDEX	POTENTIAL YIELD (PPM)
3700	Brn-gy slty sh/ coal+25% v lt gy/ lt ol-gy sst	10.97	435	244	4	0.05	26800
3750	Brn-gy/dk gy slty sh/coal+30% v lt gy/gy-red/ wht sst	8.04	433	313	4	0.08	25200

TEMPERATURE (°C) = TEMPERATURE AT MAXIMUM RATE OF PYROLYSIS
PRODUCTION INDEX = AN ESTIMATE OF PRESENT HYDROCARBON GENERATING POTENTIAL COMPARED TO THAT AT OPTIMUM MATURITY
POTENTIAL YIELD = AN ESTIMATE OF HYDROCARBON PRODUCTION AT OPTIMUM MATURITY

FIGURE I

AIRSPACE ($C_1 - C_4$) HYDROCARBONS

COMPANY : NORSK HYDRO WELL : 15/5-1 LOCATION : NORWEGIAN NORTH SEA

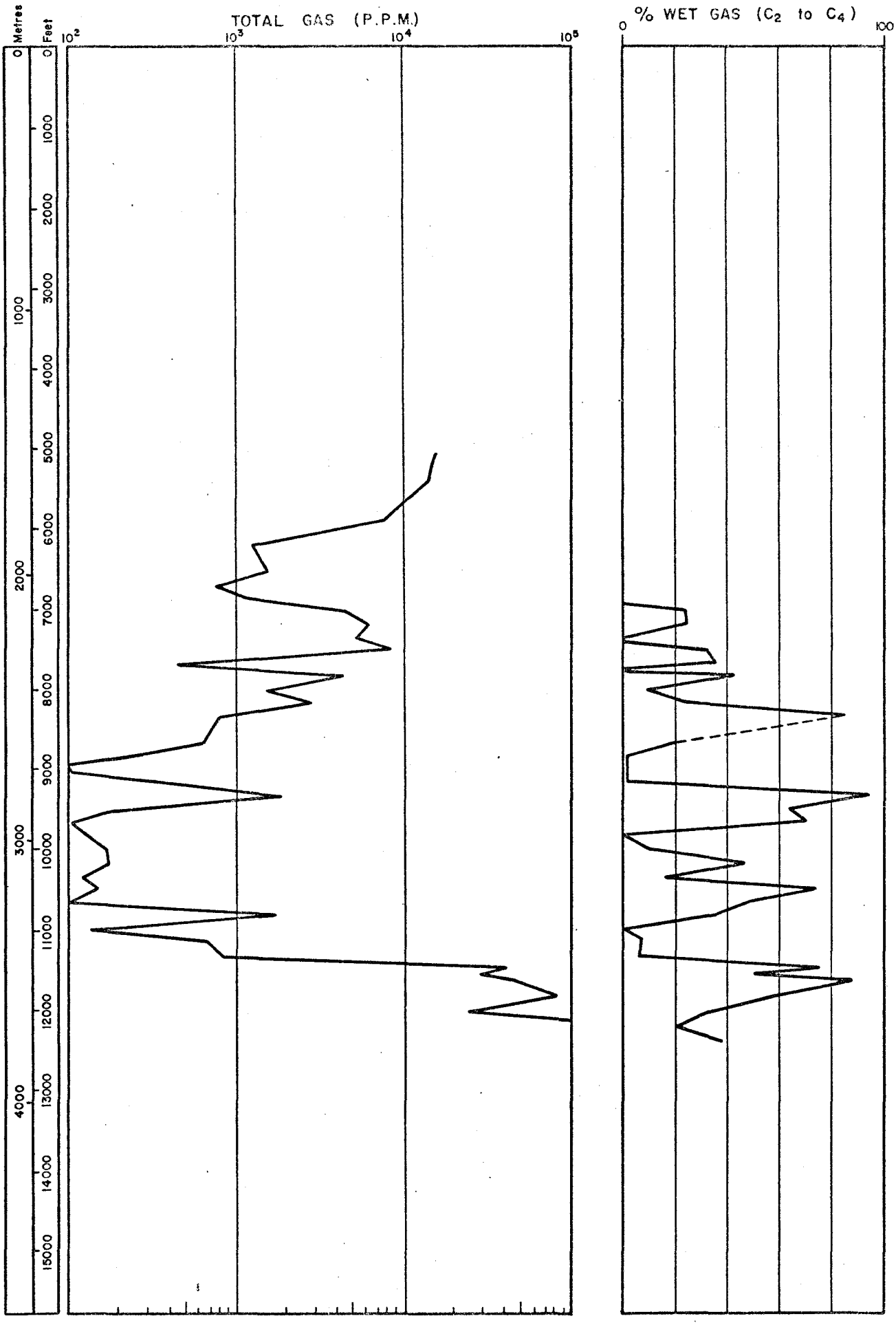
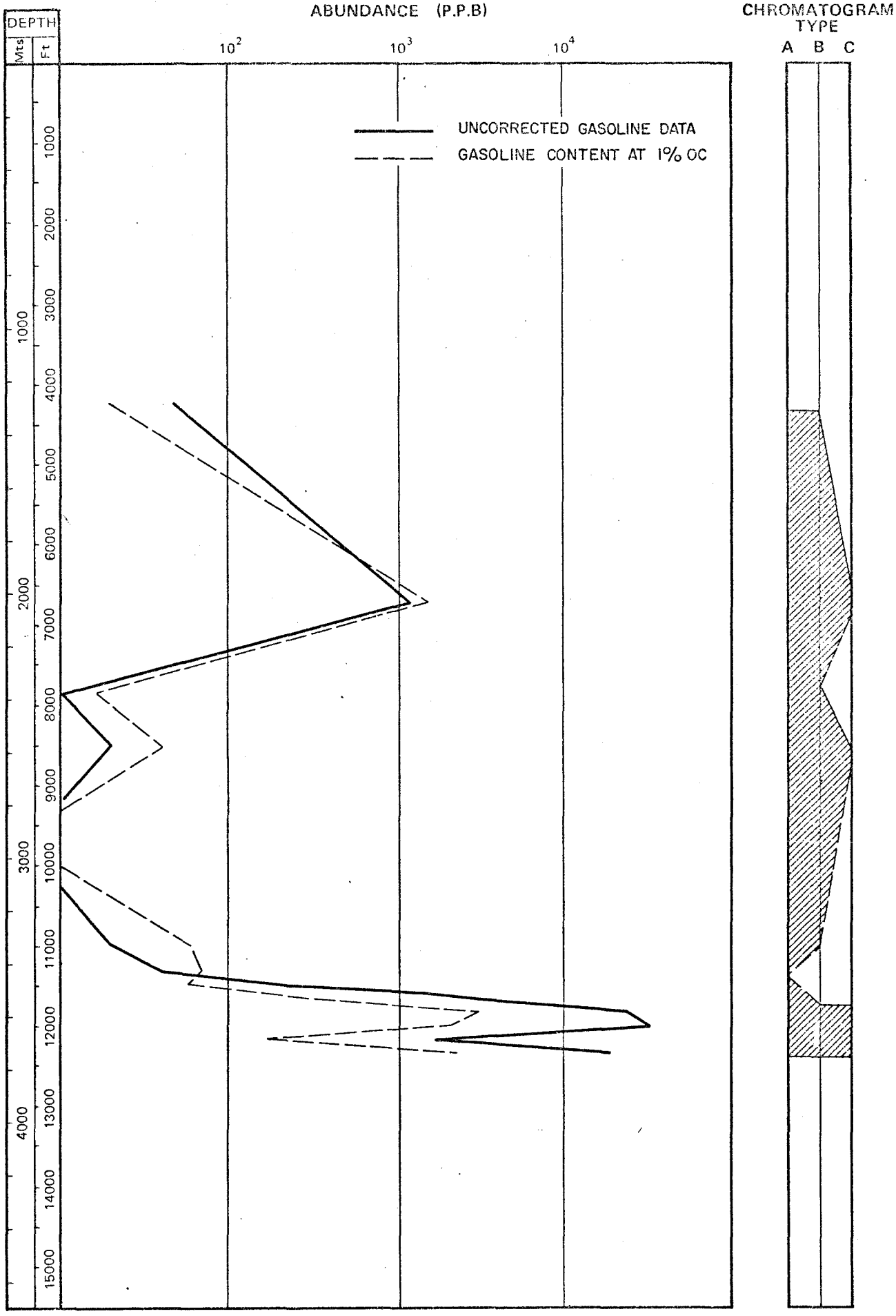


FIGURE 2 GASOLINE RANGE ($C_4 - C_7$) HYDROCARBONS

COMPANY: NORSK HYDRO WELL: 15/5-1 LOCATION: NORWEGIAN NORTH SEA



ABUNDANCE PPB CALCULATED AT 1% ORGANIC CARBON CONTENT A - IMMATURE B - TRANSITIONAL C - OIL LIKE

FIGURE 3 SPORE COLOURATION INDICES AGAINST DEPTH

COMPANY: NORSK HYDRO WELL: 15/5-1 LOCATION: NORWEGIAN NORTH SEA

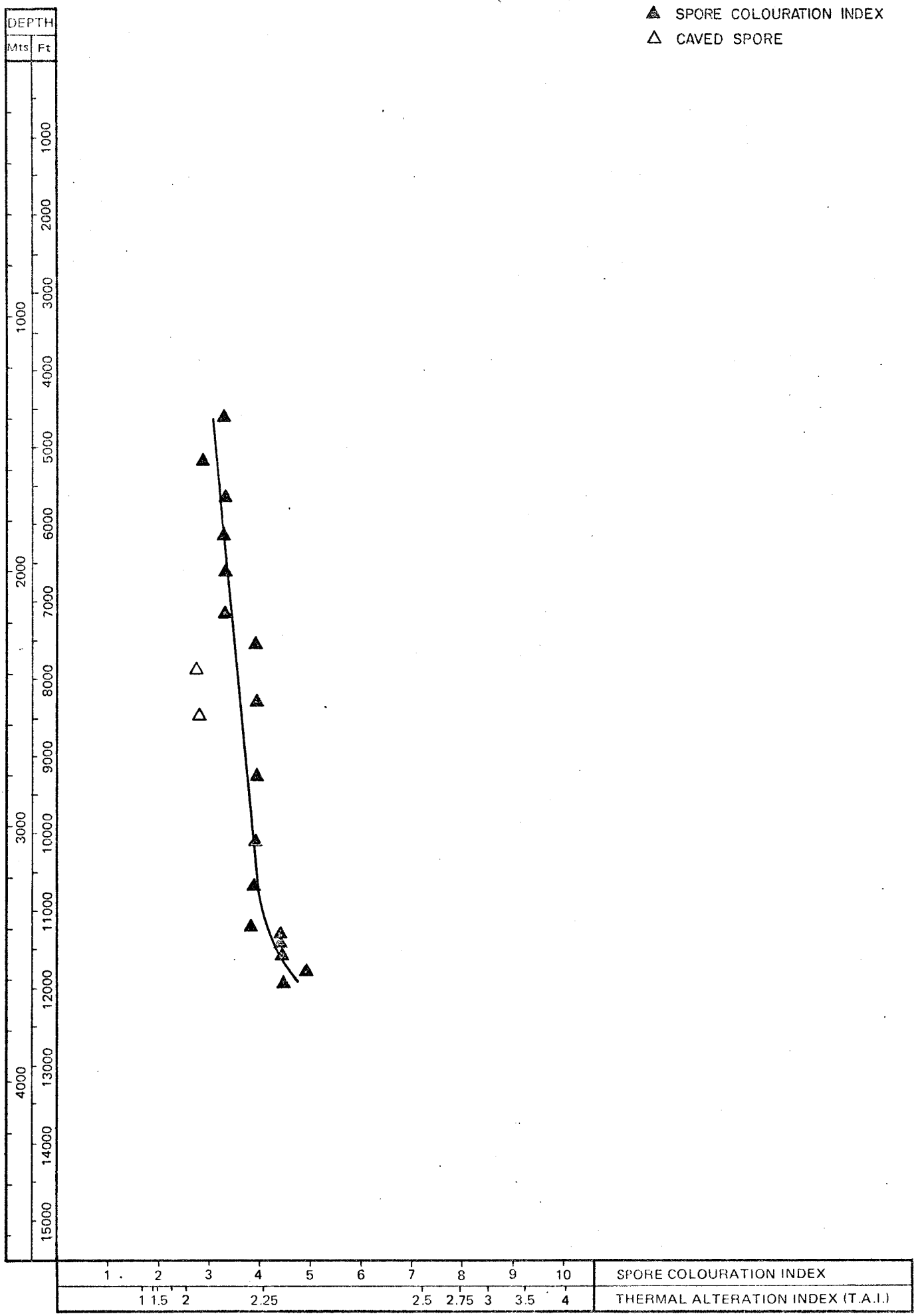


FIGURE 4 VITRINITE REFLECTIVITY AGAINST DEPTH

COMPANY: NORSK HYDRO WELL: 15/5-1 LOCATION: NORWEGIAN NORTH SEA

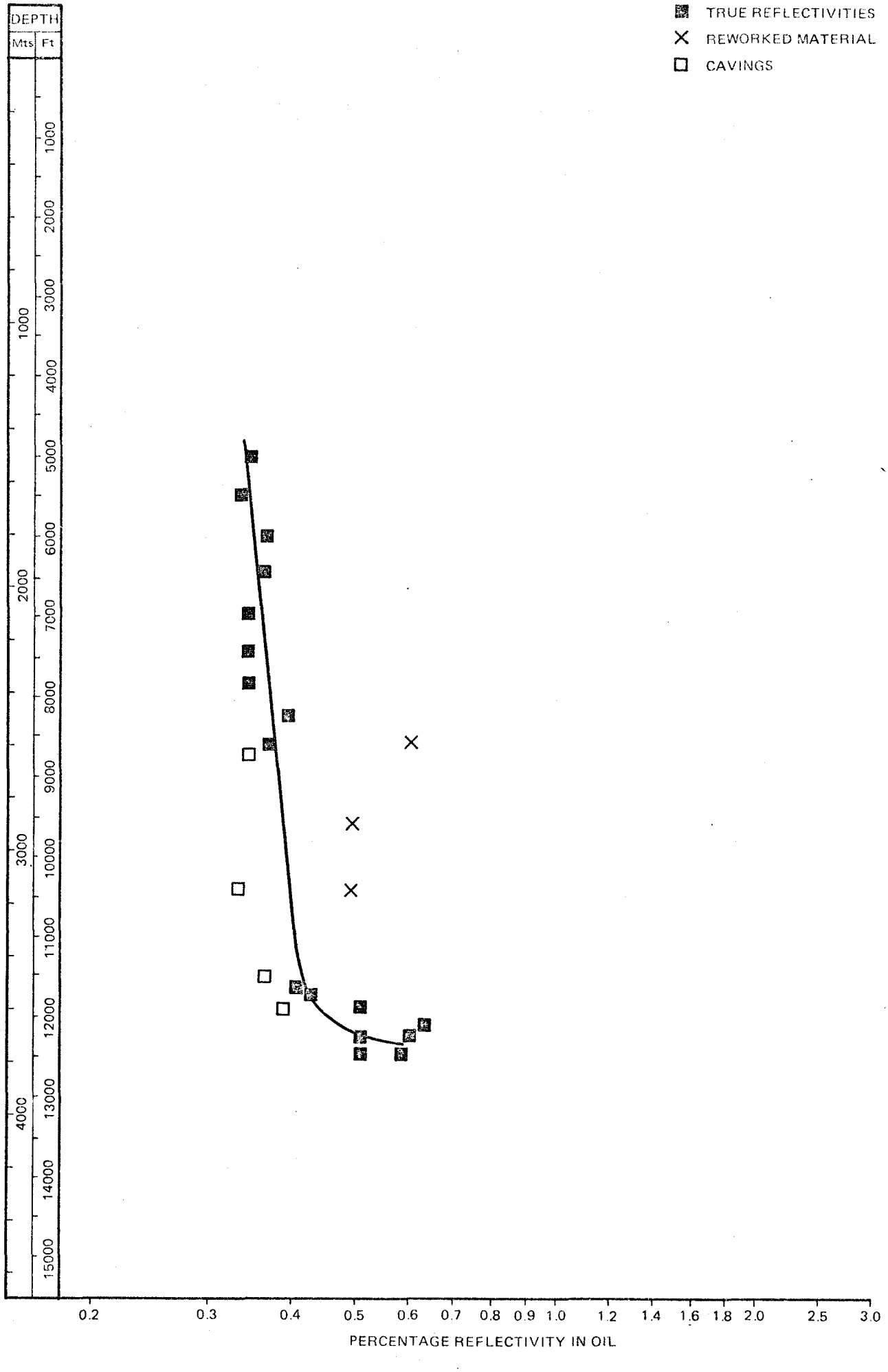


FIGURE 5

PYROLYSIS DATA SUMMARY CHART

COMPANY: NORSK HYDRO WELL: 15/5-1 LOCATION: NORWEGIAN NORTH SEA

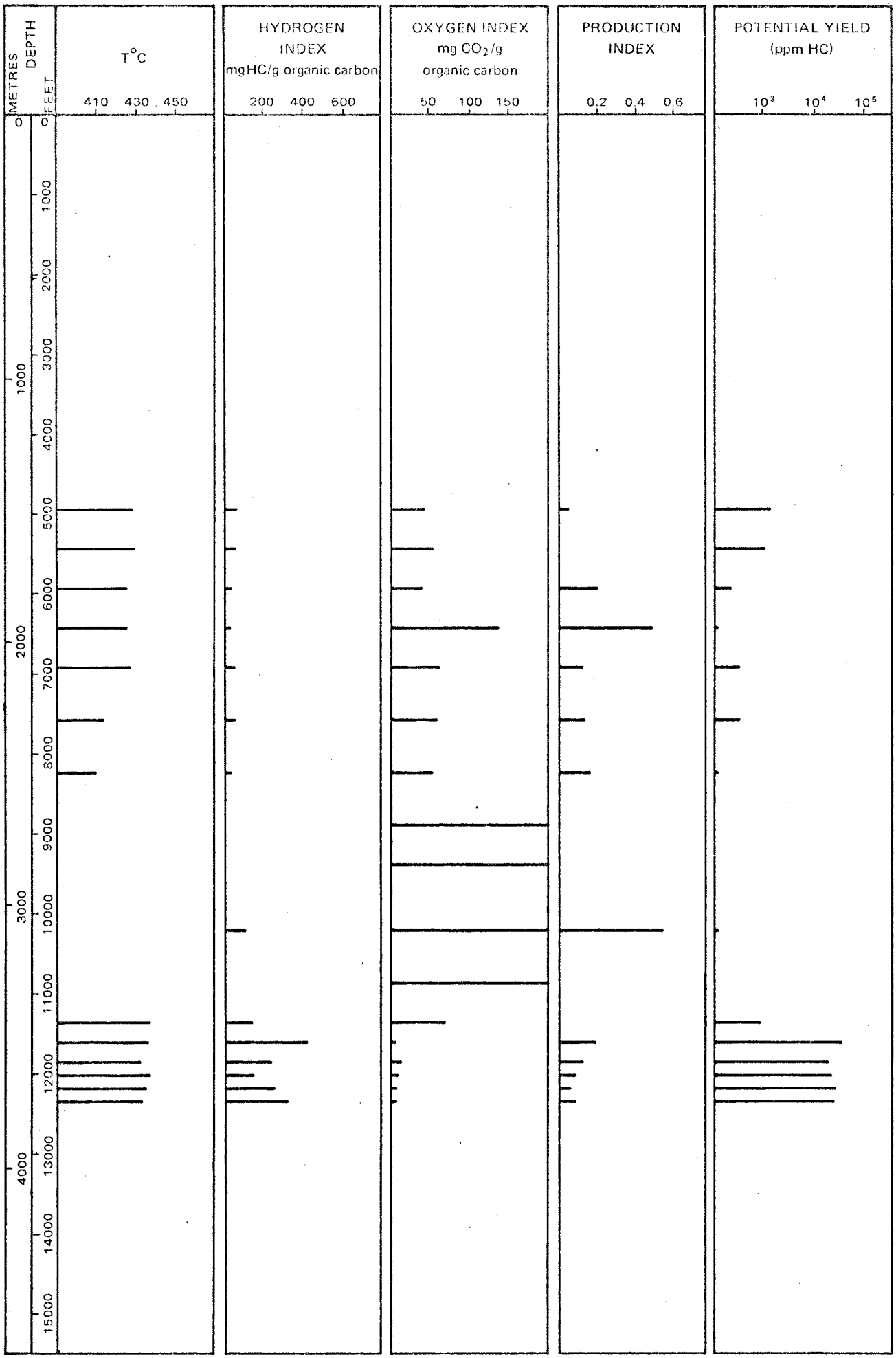
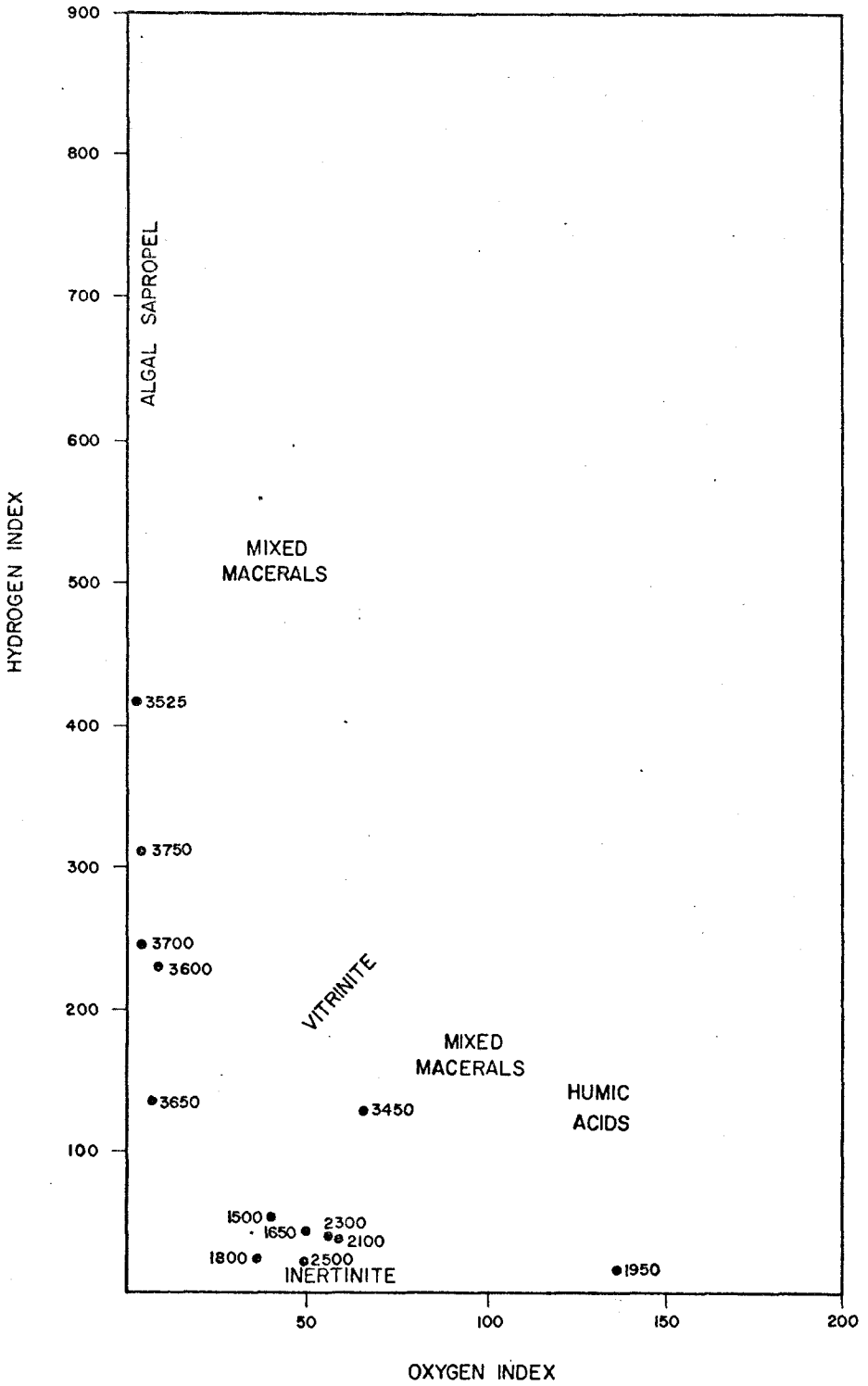


FIGURE 6

TYPE OF ORGANIC MATTER FROM PYROLYSIS DATA

COMPANY: NORSK HYDRO WELL: 15/5-1 LOCATION: NORWEGIAN NORTH SEA



Drawing No. 194P/2641/4183

GEOCHEMICAL SUMMARY CHART

FIGURE 7

COMPANY: NORSK HYDRO WELL: 15/5-1 LOCATION: NORWEGIAN NORTH SEA

SOURCE ROCK DATA

DEPTH (Metres / Feet) | STRATIGRAPHY | LITHOLOGY

ORGANIC CARBON % OF ROCK — 0.1 0.3 0.5 0.75 1.0 2.5 5.0 10.0

HYDROCARBONS PPM OF ROCK — 50 100 250 500 1000 2500

EXTRACT % OF ORGANIC CARBON — 1 2.5 5 10 20 30 50

LIKELY HYDROCARBON PRODUCT — Gas | Gas + Cond. | Cond. + Gas | Oil | Oil Stain or Contam.

SOURCE ROCK RICHNESS — Poor | Fair | Good | Very Good | Strain

SAMPLE DEPTH (Metres) AND SAMPLE TYPE

MATURATION DATA

MATURATION LEVEL OF ORGANIC MATTER — OIL-PRONE | GAS-PRONE

SUMMARY OF PRESENT POTENTIAL

Depth (m)	Depth (ft)	Stratigraphy	Lithology	Sample depth (m)	Maturation (oil-prone)	Maturation (gas-prone)	Summary of present potential
0	0	TERTIARY					
1000	3000						
2000	7000		Olive-grey/green-grey/grey shales	1500	TRANSITIONALLY MATURE		
				1650			
				1800			
				1950			
				2100			
				2300		TRANSITIONALLY MATURE	Negligible present oil & gas sourcing capability. Traces of migrant hydrocarbons present.
			Coarse sands/sandstones and grey shales	2500			
			Grey shales	2700			
3000	10000	CRETACEOUS	White/light grey/pink-grey chalks and marls	3100	MATURE		
				3300			
				3450			
				3500			
				3525			
				3550			Good oil source
				3600			
				3650		MATURE	Oil & gas source
				3700			
				3750			
		JUR.	Dark grey/olive-black shales				
			Coals, shales and sandstones				
4000	13000						
	14000						
	15000						

Casing Point

SCALE 1:20,000

Organic carbon	Hydrocarbons	Extract	Likely product	Source rock richness
Lean	Lean	Gas-prone ⟷ Oil-prone		Good gas source *
Fair	Average	Contamin.		
Aver.	Above average			
Above average				

Conv. Core

S W C

Ditch ctgs.

FIGURE 8

GAS CHROMATOGRAMS OF SATURATE HYDROCARBONS

a. 3500 m

b. 3700 m

c. 3750 m

Figure 8a 3500m

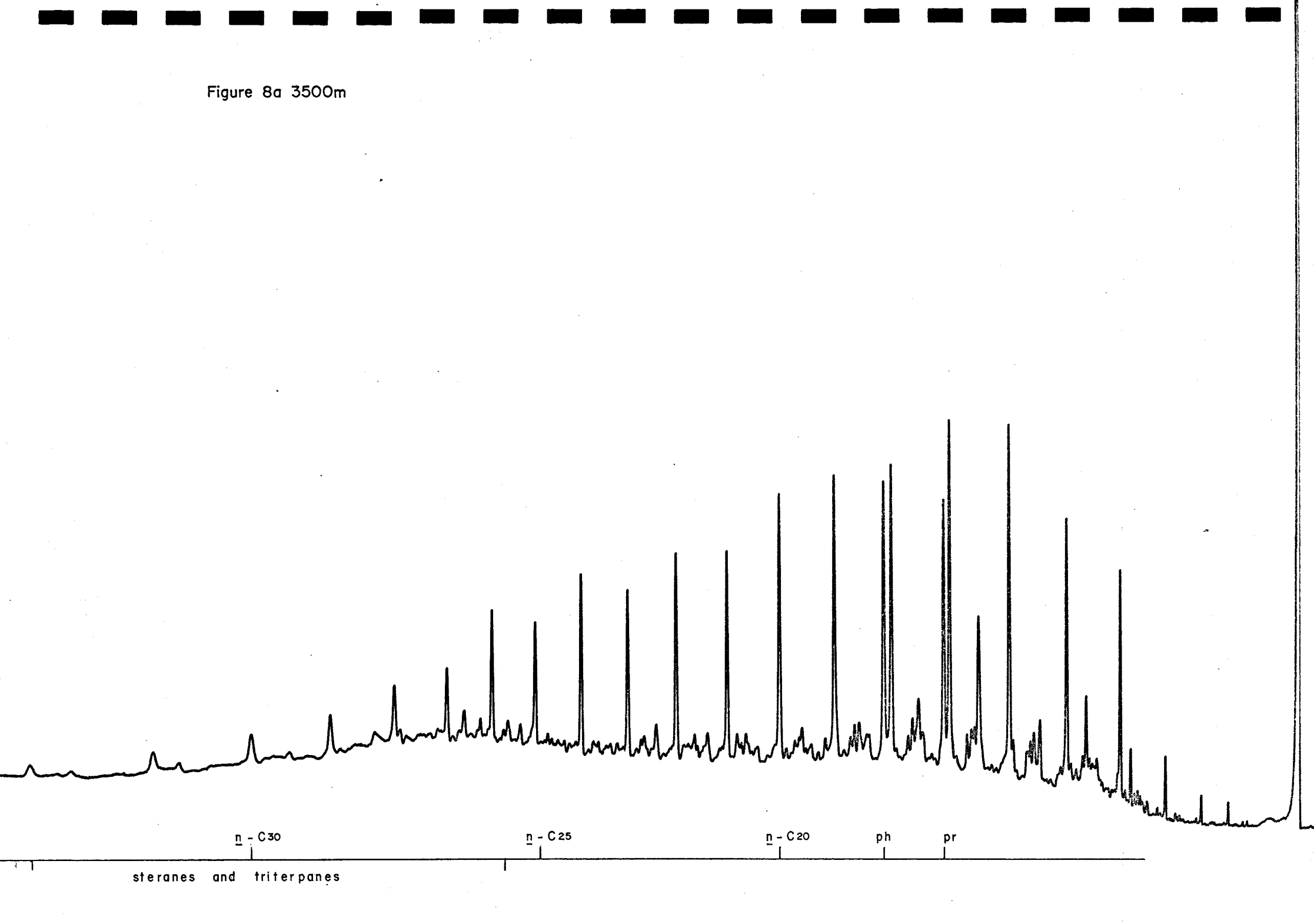


Figure 8b 3700 M.

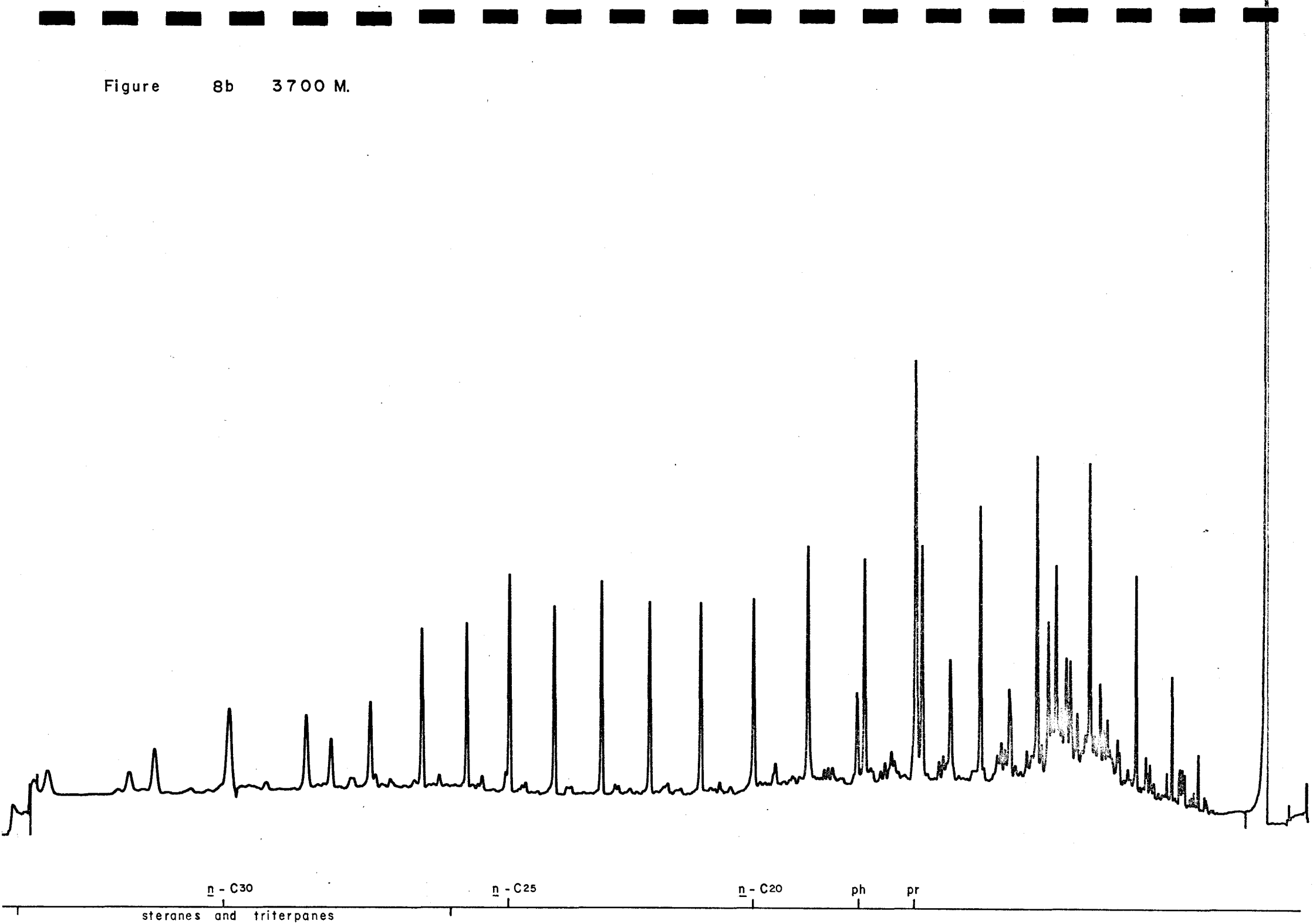


Figure 8c 3750 M.

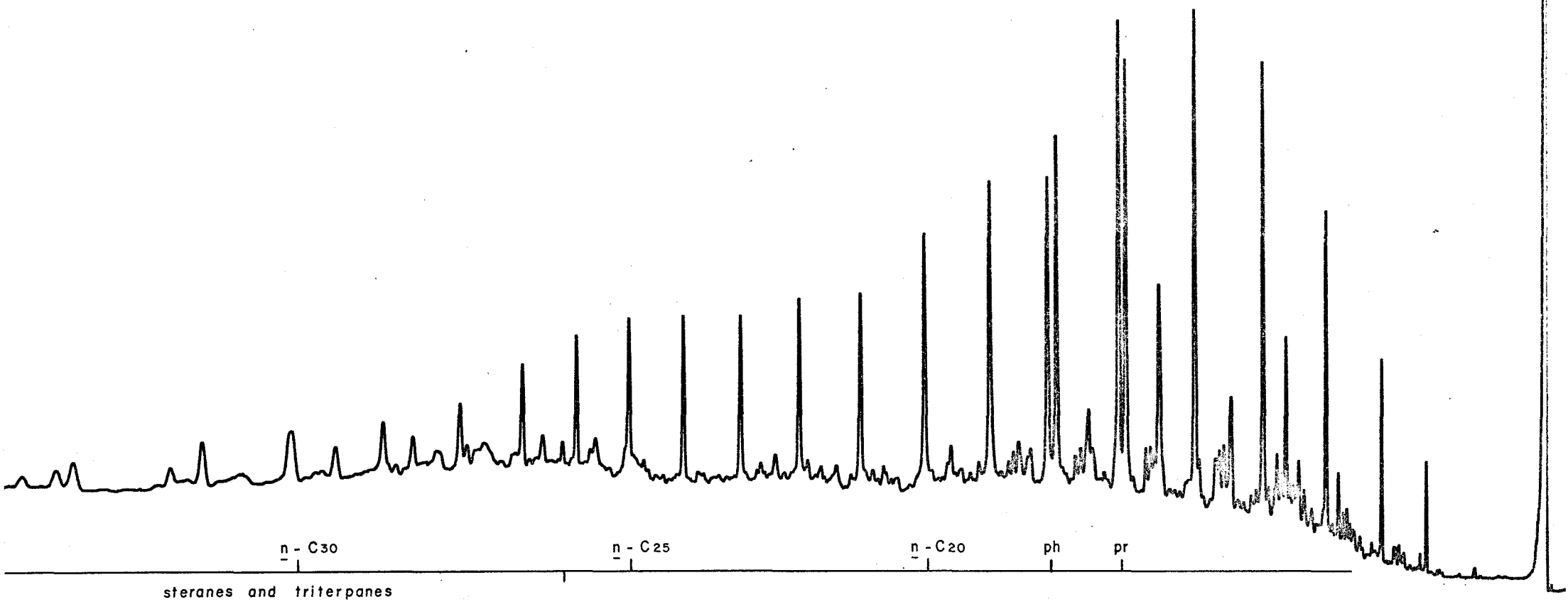


FIGURE 9

GAS CHROMATOGRAMS OF PENTANE TOTAL EXTRACTS

a. 3400-3410 m

b. 3460-3470 m

c. 3490-3500 m

Figure 9a 3400 - 3410 M.

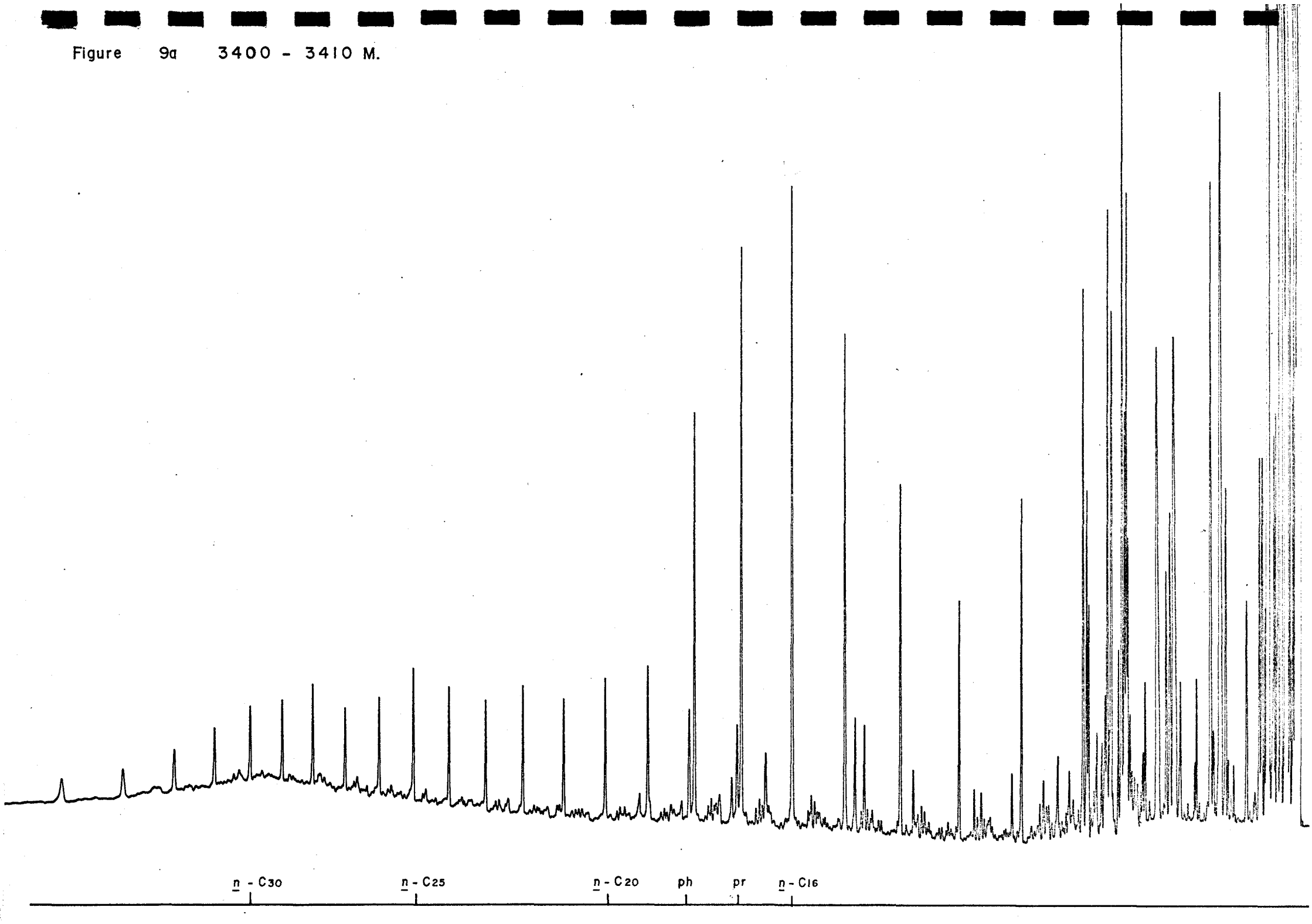


Figure 9b 3460 - 3470 M.

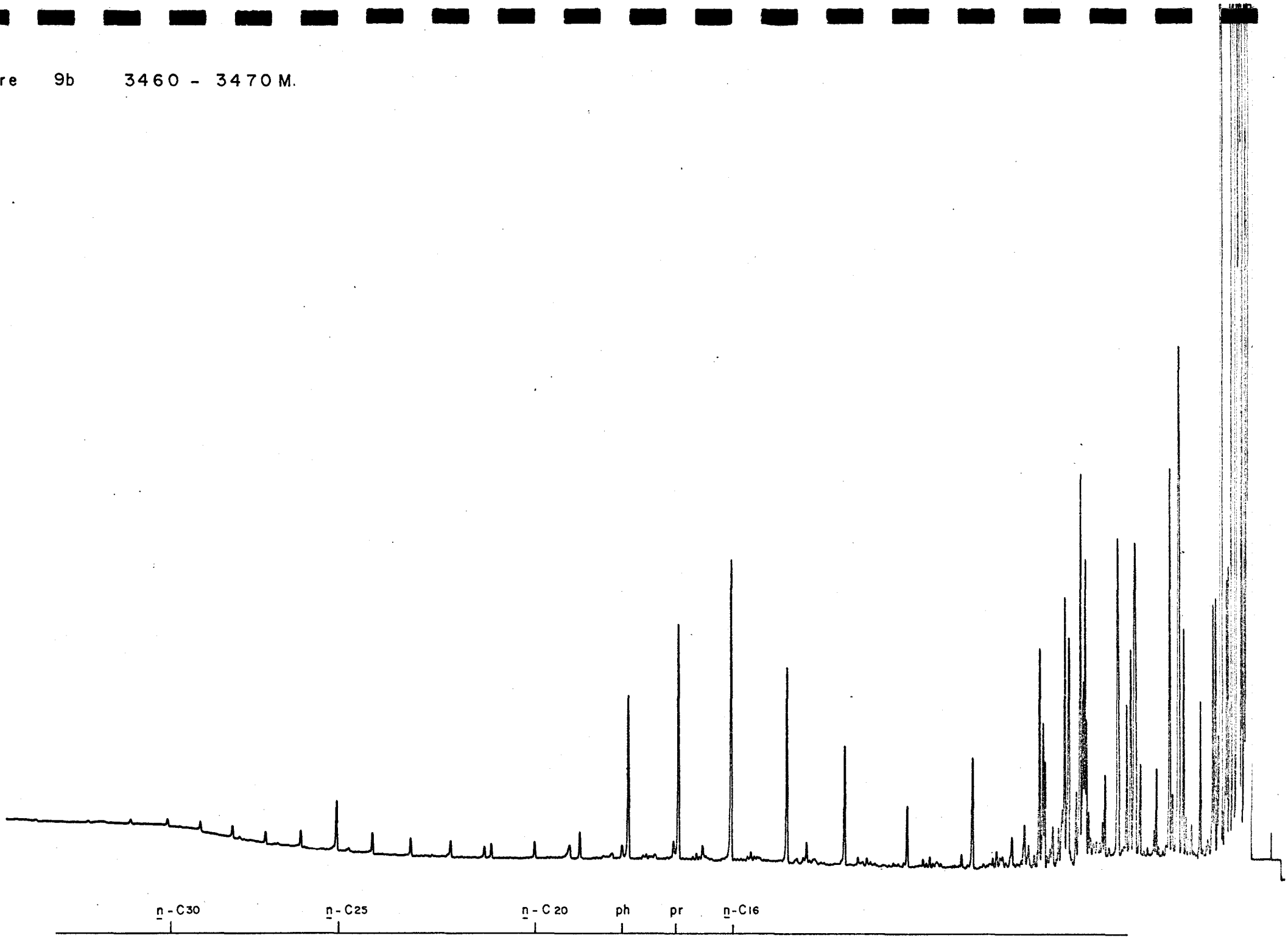


Figure 9c 3490 - 3500 M.